

Constituents of Umbelliferous Plants

XVI.* Terpenoids from the Root of *Selinum carvifolium* L.

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The ether extract of the root of *Selinum carvifolium* L., in addition to the terpene, 1,1,5-trimethyl-2-formyl-4-(3-acetoxymethyl-2-butenyloxy)-cyclohexadiene-(2,5) (I), previously isolated from this plant,¹ afforded the terpenes (III), (IV), and (V).

(III) is shown to be 1,1,5-trimethyl-2-formyl-6-((*E*)-3-acetoxymethyl-2-butenyloxy)-cyclohexadiene-(2,4). (IV) and (V) are shown to be the parent alcohols of (I) and (III), respectively. As in the case of (III), the acid moiety of (I) is shown to possess the configuration *E*.

In view of our continued interest in constituents of umbelliferous plants and prompted by the recent isolation of the ester terpenes (I) and (II) from the root of *Selinum carvifolium* L. by Bohlmann and Grenz,¹ we report on the isolation of some related terpenes from *Selinum carvifolium* L. and present additional data. In particular, a new ester terpene (III) and two terpene alcohols (IV) and (V) have been isolated in addition to (I), whereas we found no evidence, in our root material of *Selinum carvifolium* L., of the ester terpene (II).

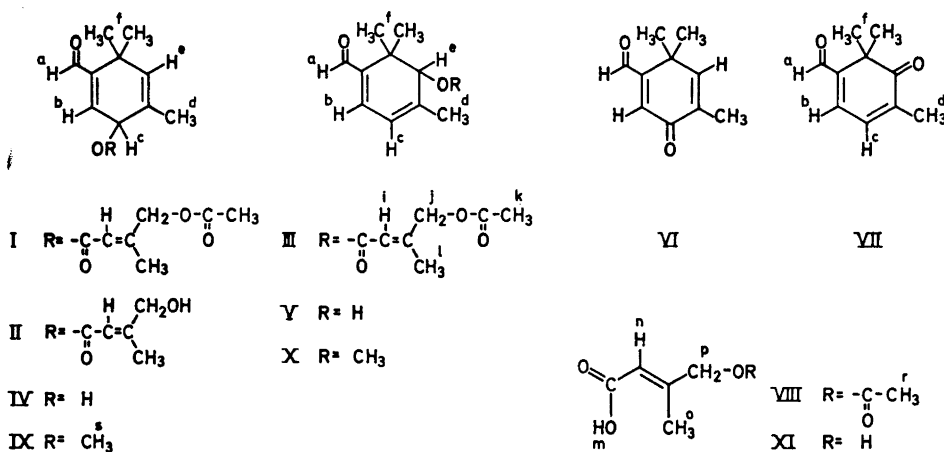
In addition, the compounds (VI)–(VIII), as well as 2,3,4-trimethylbenzaldehyde and 2,3,4-trimethylbenzoic acid were isolated, all being artifacts, formed during the isolation procedure by degradation of the genuine terpenes. Thus, (VI) and (VII) were formed by air oxidation of the alcohols (IV) and (V), respectively. Formation of the methyl ethers (IX) and (X) was observed, if the plant extract was dissolved in 90 % methanol and defatted with petroleum ether.

The ester terpene (I), an optically active liquid, on treatment with sulfuric acid in methanol solution afforded 2,3,4-trimethylbenzaldehyde and the methyl ether (X), as also described by Bohlmann and Grenz.¹ In addition, the reaction mixture afforded an acid (VIII), the constitution and configuration of which

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was evident from its degradation by alkaline hydrolysis to the known hydroxy acid (XI)² and its formation by mild acetylation of (XI). The conclusion that (I) was 1,1,5-trimethyl-2-formyl-4-((*E*)-3-acetoxymethyl-2-butenoyloxy)-cyclohexadiene-(2,5) was substantiated by the ¹H NMR- and mass spectra, which, in turn, were in accord with the data given by Bohlmann and Grenz¹ for (I), and, furthermore, by the UV- and IR-spectra.



The ester terpene (III) is an optically active liquid. The UV- and IR-spectra of (III) indicated that it was an $\alpha\beta$, $\gamma\delta$ -unsaturated aldehyde. Treatment of a methanol solution of (III) with sulfuric acid yielded 2,3,4-trimethylbenzaldehyde, the acid (VIII), and the methyl ether (X). These results are in accord with the structure 1,1,5-trimethyl-2-formyl-6-((*E*)-3-acetoxymethyl-2-butenoyloxy)-cyclohexadiene-(2,4) for the terpene (III). The ¹H NMR- and mass spectra supported this assignment. The ¹H NMR-data showed the expected similarities to those recently reported by Bohlmann and Grenz¹ for 1,1,5-trimethyl-2-formyl-6-(2-acetoxymethyl-2-butenoyloxy)-cyclohexadiene-(2,4), isolated from *Silaum silaus* S. et T.

The terpene alcohols (IV) and (V) are optically active liquids, which by UV-, IR-, ¹H NMR-, and mass spectrometry were shown to be the parent alcohols of (I) and (III), respectively. On oxidation, (IV) and (V) afforded the known³ ketoaldehyde (VI) and the ketoaldehyde (VII). A mixture of terpenes including (IV) and (V) was recently obtained from *Silaum silaus* S. et T., and their separation, after conversion to the acetates, was reported.¹ The genuine mixture of alcohols afforded ¹H NMR-data, which are in accordance with those stated in this paper for the separate compounds (IV) and (V).

EXPERIMENTAL

Melting points, UV-, IR-, and ¹H NMR-spectra (CCl₄) were determined as described in previous papers.^{4,5} The mass spectra were recorded on a Varian Mat CH-5 instrument (direct inlet) at 70 eV; ion source temperature 100°; sample temperature 10–60°; ionization

current 100 μ A; m/e values and intensities of peaks higher than 15 % (for compound (III) 5 %) of base peak, and of a few less intense, but pertinent peaks, are stated. Microanalyses were performed by Dr. A. Bernhardt, Elbach über Engelskirchen. The silica gel (Merck 0.05–0.20 mm) used in column chromatography was activated at 120° overnight and impregnated with 10 % of water. The optical rotation values were determined on a Perkin-Elmer Polarimeter, Model 141.

The plant material was collected in September near Copenhagen. The dried and ground roots (840 g) on extraction with ether, and subsequent evaporation of the solvent, afforded 30 g of extract, which was chromatographed on 400 g of silica gel. The sequence of eluents was petroleum ether, to which increasing amounts of ether were added (10–50 %), petroleum ether-ether (1 : 1) containing 20 to 100 % of ethyl acetate, and, finally, ethyl acetate, to which increasing amounts of methanol were added. Fractions containing the compounds (IV) and (V) were rechromatographed on silica gel, using benzene, to which ethyl acetate (10–20 %) was added, as eluent.

The following compounds (*a-h*) were obtained (described in order of elution):

a. 2,3,4-Trimethylbenzaldehyde. A colourless liquid, b.p. 122–123°/11 mm (Ref. 6, b.p. 121°/11 mm). The ¹H NMR-spectrum and the analytical data were consistent with the assigned structure. The following derivatives were prepared: the 2,4-dinitrophenylhydrazone, m.p. 234–235° (methanol) (Ref. 3, m.p. 223°; Ref. 7, m.p. 227–229°); the oxime, m.p. 130–131° (aq. ethanol) (Ref. 6, m.p. 131–132°); and by air oxidation, 2,3,4-trimethylbenzoic acid, m.p. 169–169.5° (aq. ethanol) (Ref. 8, m.p. 167.5°). The analytical data of the derivatives were in accord with the values calculated.

b. 1,1,5-Trimethyl-2-formyl-cyclohexadiene-(2,5)-one-4 (VI). A yellow crystalline compound, m.p. 58–59° (petroleum ether). The UV-, IR-, ¹H NMR-, and mass spectra were in accordance with the data given by Bohlmann and Zdero.³

c. 1,1,5-Trimethyl-2-formyl-cyclohexadiene-(2,4)-one-6 (VII). A yellow liquid, which crystallizes upon standing, m.p. 25–30°. UV: λ_{\max} (EtOH) 316 nm (3.98) shoulders at λ 302 nm (3.90) and 332 nm (3.82). IR: 2710, 1685 (CHO), 1665 (CO), 1575 (conj. C=C). ¹H NMR-data (δ values): doublets at 6.84 (1H) ($J_{b,c}$ = 6 cps), 1.96 (3H) ($J_{c,d}$ = 1.5 cps), and a multiplet at 7.03 (1H) are assigned to the protons *b*, *d*, and *c*, respectively, a singlet at 9.44 (1H), to the aldehyde proton *a*, and a singlet at 1.37 (6H), to the *gem*-dimethyl protons *f*. Mass spectrum (sample temp. 10–15°): 164 (M^+ , 100), 149 (19), 136 (99), 135 (96), 121 (52), 108 (15), 107 (30), 95 (15), 93 (89), 91 (71), 79 (23), 77 (43), 67 (18), 65 (26), 53 (21), 51 (22), 41 (35), 39 (40).

d. 1,1,5-Trimethyl-2-formyl-4-((E)-3-acetoxymethyl-2-butenyloxy)-cyclohexadiene-(2,5) (I). A viscous liquid (11.2 g), $[\alpha]_D^{20} + 81^\circ$ (*c* 1.0, CCl₄). UV: λ_{\max} (EtOH) 226 nm (4.43). IR: 2710, 1710 (CHO), 1740, 1215 (CH₃COO-), and 1650 cm⁻¹ (C=C). The ¹H NMR- and mass spectra were in accordance with the data given by Bohlmann and Grenz.¹

e. 1,1,5-Trimethyl-2-formyl-6-((E)-3-acetoxymethyl-2-butenyloxy)-cyclohexadiene-(2,4) (III). A viscous liquid (1.3 g), $[\alpha]_D^{20} + 257^\circ$ (*c* 1.2, CCl₄). (III) is unstable even when stored at –20°. Partly deteriorated samples, upon rechromatography afforded samples of (III) with lower rotation values, presumably as a consequence of optical instability. UV: λ_{\max} (EtOH) 215 nm (4.21) and 301 nm (4.01). IR: 2710, 1710 (CHO), 1745, 1220 (CH₃COO-), and 1575 cm⁻¹ (conj. C=C). ¹H NMR-data (δ values): a singlet at 9.35 is assigned to the aldehyde proton *a*, doublets at 6.58 (1H) ($J_{b,c}$ = 6 cps), 1.90 (3H) ($J_{c,d}$ = 1.5 cps), and a multiplet at 6.05 (1H) to the protons *b*, *d*, and *c*, respectively, a singlet at 5.15 (1H) to the proton *e*, two singlets at 1.20 and 1.11 (3H each) to the *gem*-dimethyl protons *f*. The acid moiety of (III) gives rise to a quartet at 5.72 (1H) and a doublet (3H) at 2.11 ($J_{i,l}$ = 1 cps), assigned to the protons *i* and *l*, respectively, a slightly broadened singlet (2H) at 4.50 to the protons *j*, and a singlet (3H) at 2.07 to the acetyl protons *k*. Mass spectrum (sample temp. 55°): 306 (M^+ , 2), 231 (2), 208 (1.4), 166 (9), 151 (2), 137 (7), 136 (5), 121 (6), 105 (6), 100 (6), 99 (100), 82 (10), 43 (43).

f. 1,1,5-Trimethyl-2-formyl-cyclohexadiene-(2,5)-ol-4 (IV). An oily liquid (0.3 g), $[\alpha]_D^{20} + 15^\circ$ (*c* 1.0, CHCl₃). UV: λ_{\max} (EtOH) 228 nm (3.94). IR: 3380 (OH), 2720, and 1690 cm⁻¹ (CHO). The ¹H NMR-spectrum was in accordance with the data given by Bohlmann and Grenz.¹ Mass spectrum (sample temp. 10–15°): 166 (M^+ , 47), 151 (17), 137 (100), 123 (80), 122 (20), 121 (20), 109 (15), 108 (36), 107 (20), 105 (26), 95 (18), 91 (22), 79 (22), 77 (37), 69 (15), 67 (17), 55 (16), 53 (16), 51 (17), 43 (37), 41 (31), 39 (37).

Oxidation of (IV) (1 mg in 0.2 ml CCl₄) with MnO₂ (1 h, at room temperature) yielded the ketoaldehyde (VI), identified by TLC and UV-spectroscopy.

g. *1,1,5-Trimethyl-2-formyl-cyclohexadiene-(2,4)-ol-6 (V)*. An oily liquid (0.2 g), $[\alpha]_D^{20} + 45^\circ$ (c 1.0, CHCl_3). UV: λ_{max} (EtOH) 305 nm (3.97). IR: 3420 (OH), 2710, 1670 (CHO), and 1570 cm^{-1} (conj. C=C). The ^1H NMR-spectrum was in accordance with the data given by Bohlmann and Grenz.¹ Mass spectrum (sample temp. $10-15^\circ$): 166 (M^+ , 17), 151 (5), 148 (7), 137 (47), 133 (27), 124 (15), 123 (100), 122 (21), 121 (20), 120 (17), 119 (17), 109 (20), 107 (17), 105 (33), 95 (24), 91 (26), 84 (74), 83 (20), 79 (20), 77 (29), 70 (22), 69 (15), 67 (21), 55 (34), 53 (18), 45 (16), 43 (94), 42 (15), 41 (40), 39 (35). Air oxidation of (V) yielded the ketoaldehyde (VII), identified by TLC and UV-spectroscopy.

h. *(E)-3-Acetoxyethyl-2-butenoic acid (VIII)*. Colourless needles, m.p. $56-57^\circ$ (petroleum ether-ether). (Found: C 53.37; H 6.38. Calc. for $\text{C}_9\text{H}_{16}\text{O}_4$: C 53.16; H 6.37.) UV: λ_{max} (EtOH) 213 nm (4.12). IR: 1725, 1222 ($\text{CH}_3\text{COO}-$), 1695 (C=O), and 1645 cm^{-1} (C=C). ^1H NMR-data (CDCl_3 , δ values): a broad singlet at 11.73 (1H), which disappears upon exchange with D_2O , is assigned to the proton *m*. A broad pattern at 5.92 (1H) is assigned to the proton *n*, a slightly broadened singlet (2H) at 4.65 to the protons *p*, and a slightly broadened singlet (6H) at 2.15 to the methyl protons *o* and *r*.

Saponification of (VIII). A solution of (VIII) (80 mg) in 0.2 N ethanolic potassium hydroxide (8 ml) was kept at 40° for $\frac{1}{2}$ h. The reaction mixture was worked up using a column extraction technique previously described.⁹ *(E)-3-Hydroxymethyl-2-butenoic acid (XI)* (56 mg), m.p. $110.5-111^\circ$ (petroleum ether-ethyl acetate) was obtained. The analytical data were concordant with the composition $\text{C}_5\text{H}_8\text{O}_3$. UV: λ_{max} (EtOH) 216 nm (4.09) (Ref. 2, m.p. 113° , λ_{max} (EtOH) 219 nm (4.13)).

Acetylation of (XI). A solution of (XI) (20 mg) in a mixture of acetic anhydride (0.2 ml) and pyridine (0.3 ml) was kept at room temperature for $\frac{1}{2}$ h, and then one drop of water was added. Upon evaporation of the solvents, the residue was chromatographed on silica gel (5 g). The eluent was benzene-formic acid (100:0.2) to which increasing amounts of ethyl acetate (20-50%) were added. 27 mg of (VIII) were obtained as a colourless oil. Crystallization from petroleum ether-ether yielded needles with m.p. $55-56^\circ$. The IR-spectrum was identical with that of the sample of (VIII), described above.

Treatment of (III) with sulfuric acid. A solution of (III) (156 mg) in a mixture of methanol (3 ml) and 4 N sulfuric acid (0.2 ml) was kept at 50° for 10 min. The reaction mixture was diluted with water (3 ml) and extracted with methylene chloride. The methylene chloride phase was washed with sodium hydrogen carbonate solution, dried, and evaporated to dryness. The residue (68 mg) was chromatographed on silica gel (5 g) using petroleum ether-ether mixtures as eluents. 2,3,4-Trimethylbenzaldehyde (19 mg) and an optically inactive methyl ether (X) (14 mg) with λ_{max} (EtOH) 306 nm (4.03) was obtained. The ^1H NMR-spectrum of (X) was in accordance with the data given by Bohlmann and Grenz.¹ The water phase and the sodium hydrogen carbonate phase, mentioned above, were mixed and worked up, using the column extraction technique, described above. *(E)-3-Acetoxyethyl-2-butenoic acid (VIII)* (53 mg), which after recrystallization melted at $54.5-56^\circ$ (petroleum ether), was obtained.

Treatment of (I) with sulfuric acid. A solution of (I) (63 mg) in a mixture of methanol (2 ml) and 4 N sulfuric acid (0.2 ml) was kept at 50° for 2 min. Using the procedure described above the following compounds were obtained: 2,3,4-trimethylbenzaldehyde, the methyl ether (X), and the acid (VIII) (m.p. $53-54^\circ$, petroleum ether-ether).

1,1,5-Trimethyl-2-formyl-4-methoxy-cyclohexadiene-(2,5) (IX). When the plant extract was dissolved in 90% methanol and defatted with petroleum ether, the defatted extract, in addition to the above mentioned compounds *a-h*, yielded (IX). (IX) is an optically inactive, viscous liquid. UV: λ_{max} (EtOH) 224 nm (3.92). ^1H NMR-data (δ values: a doublet at 9.41 (1H) is assigned to the aldehyde proton *a* ($J_{a,e} = 0.7$ cps), a doublet at 6.49 (1H) ($J_{b,c} = 4$ cps) to the proton *b*, a multiplet at 4.48 (1H) to the proton *c*, a perturbed doublet at 1.74 ($J_{c,d} = ca. 1$ cps) to the methyl protons *d*, a slightly broadened singlet at 5.40 (1H) to the proton *e*, and singlets at 3.06, 1.24, and 1.19 (3H each) to the methoxy protons *s* and the *gem*-dimethyl protons *f*, respectively. The long range coupling between the aldehyde proton *a* and the proton *e* was confirmed by decoupling experiments.

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